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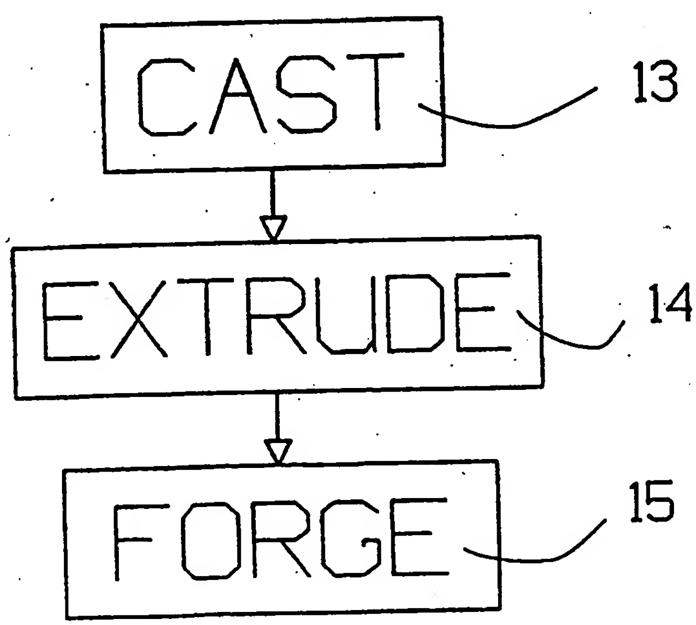
(54) Title: METAL SHAPING SYSTEM

(57) Abstract

A method for making a cast and forged metal article (20), comprising the steps of, a) preparing an expendable pattern of the part to be cast, b) dipping said pattern into slurry of fused silica and a binder to form a moist coating, c) sprinkling silicon carbide grit on said moist coating, d) drying said moist coating, e) repeating steps b), c), and d) until said shell (37) is built up to the desired thickness, and f) casting a metal article (20) in said mold (37) to form a preform blank, and g) subjecting said preform blank to extrusion (14), closed die forging (15), or both, to produce desired mechanical properties and microstructure. The alloy is a cobalt based metal alloy, wherein the carbon content of said cobalt based alloy is above 0.2 % by weight. The final forged workpiece is a hip replacement. A metal–matrix composite comprising a uniform distribution of ceramic particles (31) within a metal matrix (32) formed of a metal having a melting point above 1000 °C and a specific gravity of at least 4. The particles (31) are aluminum oxide or zircon. The metal (32) is a stainless steel.



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METAL SHAPING SYSTEM

FIELD OF THE INVENTION

This invention concerns the shaping of metal articles.

BACKGROUND OF THE INVENTION

The present invention relates to a method of making a metal article by a combination of casting and forging, more specifically, to make such an article by forging a cast preformed blank.

Heretofore, metal articles were manufactured commercially by either casting or forging. The choice of one manufacturing process excluded the other.

It is well known that, as a general rule, forged articles are stronger and have better physical properties than cast articles, but are typically more expensive. On the other hand, cast articles, in addition to being cheaper to manufacture, are more easily made into intricate shapes and can tolerate higher levels of carbon content. For example, cobalt-based alloys having a high carbon content by weight are considered unsuitable for certain forging applications and indeed, such alloys can be difficult to mechanically work. The casting process readily accepts high carbon alloys.

Forging stock is prepared by rolling the hot ingot after it is poured from the furnace. During the rolling operations some impurities are removed and the physical properties are improved, in particular, the ductility.

Ductile strength, the ability to withstand some stretching and bending without breaking, is essential to making the material suitable for forging. Forging stock is sold as rods or bars to forging manufacturers.

Due to the fact that cast articles do not have physical properties comparable to a forging , especially ductility, castings are not considered suitable for forging or use as forging stock. This is especially true of cast articles made from alloys containing high concentrations of carbon or other elements that reduce the ductile strength of the metal.

An ancient art of making castings is known as the investment casting or the lost wax process. In such a process, an expendable pattern of the part to be cast is made, for example, in wax. The wax pattern is then dipped into ceramic slurry, removed and a coarse refractory grit is sprinkled on the wet slurry coating and allowed to dry and harden. This process is repeated several times until a sufficiently thick layer is built up on the wax pattern. Drying can be carried out after each layer is applied. After the final thickness is reached, the entire assembly is allowed to dry and set. The wax is then removed from the mold by one of several techniques, such as in a steam autoclave or flashfire furnace.

The mold is then preheated to an appropriate temperature and the molten metal is poured into it. After the metal has solidified, the mold is broken away and a cast article is removed.

Instead of wax, the expendable pattern may be formed of polystyrene, polycarbonate, modified wax and the like. The ceramic slurry ordinarily is a water dispersion of silica. The usual refractories employed in the process are silica, zircon, aluminosilicates and the like. Silicon carbide, although a recognized refractory material, is comparatively much more expensive than silica, and, therefore, is not generally considered a substitute for the more conventional refractories. However, silicon carbide has been used to provide a wear resistant layer in a metal mold and deposited electrolytically in a bath as disclosed in U.S. Patent No. 4,197,902.

Although the art of casting and the lost wax process have a history of many thousands of years, there is much that is unknown about how variations in the process affect the physical properties of the metal. There also is much that is unknown about how freezing effects metal properties.

The known processes do not always allow complete control and selection of alloy chemistries, do not always allow full optimization of physical properties, do not always allow complete freedom of choice as to product shape, and do not always provide availabity of near-net shape results.

These and other difficulties experienced with the prior art metal shaping systems have been obviated in a novel manner by the present invention.

An object of the invention is to prepare a cast article which can subsequently be forged as by extrusion or closed die forging.

Another object of the invention is to provide a casting of high soundness, fine grain and increased mechanical strength (particularly yield strength and elongation) so that it can be used in forging.

Another object of the invention is to produce a product that exceeds all minimum forging requirements while at the same time allows for wide variations in available chemical composition to satisfy specific product applications.

Another object of the invention is to provide a novel casting mold characterized by a high heat capacity and high heat conductivity which equates to the high heat diffusivity that is needed for the quick cooling necessary to produce the desired forgability.

Another object of the invention is to provide a mold for rapidly extracting heat during the solidification phase of the cast cooling process.

Another object of the invention is to produce a hybrid product with a combination of forged and cast microstructure and mechanical strengths that may be less than a forging but are greater than a casting.

Another object of the invention is to produce a metal matrix composite which has the strength, chemical resistance, fracture resistance, and temperature resistance of high performance metals such as stainless steel, high heat capacity and wear resistance of ceramics, and reduced density relative to strength.

With the foregoing and other objects in view, which will appear as the description proceeds, the invention resides in the combination and arrangement of steps and the details of the composition hereinafter described and claimed, it being understood that changes in

the precise embodiment of the invention herein disclosed may be made within the scope of what is claimed without departing from the spirit of the invention.

BRIEF SUMMARY OF THE INVENTION

This invention is method for making a cast and forged metal article, comprising the steps of, a) preparing an expendable pattern of the part to be cast, b) dipping said pattern into slurry of fused silica and a binder to form a moist coating, c) sprinkling silicon carbide grit on said moist coating, d) drying said moist coating, e) repeating steps b), c), and d) until said shell is built up to the desired thickness, and f) casting a metal article in said mold to form a preform blank, and g) subjecting said preform blank to extrusion, closed die forging or both to produce desired mechanical properties and microstructure. The alloy is a cobalt based metal alloy, wherein the carbon content of said cobalt based alloy is above 0.2% by weight. The final forged workpiece is a hip replacement. A metal-matrix composite comprising a uniform distribution of ceramic particles within a metal matrix formed of a metal having a melting point above 1000 deg. C. The particles are aluminum oxide or zircon. The metal is a stainless steel.

Briefly stated, the present invention relates to preparing an article by casting a preform blank and then forging said cast preform blank. The present invention also relates to preparing a mold in which said casting is made using silicon carbide in sufficient amounts and sufficient densities to rapidly extract the heat from the casting during the solidification phase, so that the resulting grain structure increases the ductile strength to about 50% higher than industry standard minimums for the same alloys and further to utilize this casting to produce a 100% dense forged product with all the physical strength and microstructure of a forging.

BRIEF DESCRIPTION OF THE DRAWINGS

The character of the invention, however, may best be understood by reference to one of its structural forms, as illustrated by the accompanying drawings, in which:

Figure 1 shows a flow chart of a process which embodies the principles of the present invention,

Figure 2 shows a flow chart of a process which embodies the principles of the present invention,

Figure 3 shows diagrammatic view of the first step in an extrusion process which embodies the principles of the present invention,

Figure 4 shows diagrammatic view of the second step in an extrusion process which embodies the principles of the present invention,

Figure 5 shows diagrammatic view of the third step in an extrusion process which embodies the principles of the present invention,

Figure 6 shows diagrammatic view of the fourth step in an extrusion process which embodies the principles of the present invention,

Figure 7 shows diagrammatic view of the fifth step in an extrusion process which embodies the principles of the present invention,

Figure 8 shows diagrammatic view of the sixth step in an extrusion process which embodies the principles of the present invention, and

Figure 9 shows diagrammatic view of a melt and cast system for use with a metal matrix composite which embodies the principles of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

In accordance with the objects of the invention, it has been discovered that , if the heat is rapidly extracted from the mold during the solidification range, the resulting cast article surprisingly can be forged. Moreover, this cast article can be used as a preform blank for a forge operation. - i.e. an extrusion process or closed die forging.

The invention takes two forms. The first form, cast-forge, shown diagrammatically in Figure 1, begins by casting 11 the metal to an enlarged but near-net shaped preform

blank. The blank is then forged 12 to the final shape. The second form, cast-extrude-forge, shown diagrammatically in Figure 2, begins by casting 13 the metal to a rod. The rod is then extruded 14, the resulting extruded rod is then forged 15 to the final shape.

It has also been discovered that a mold prepared from alternating layers of fused silica slurry and silicon carbide stucco with primary slurries using silicate and zircon provides high heat diffusivity or a combination of high heat capacity and high heat conductivity and that cast articles made from such a mold exhibit finer cast grain and the higher ductility needed for forging.

The basic method for making the shell mold by investment casting is comprised of: 1. making an expendable pattern to the desired shape, 2. precoating with silica and zircon to provide a non-reactive mold-metal interface, 3. dipping the expendable pattern into a slurry of fused silica and a binder to form a moist coating on the pattern, 4. sprinkling a coarse silicon carbide grit on to the moist coating, 5. allowing to dry, 6. repeat the dipping and sprinkling process until the desired thickness of the mold is achieved.

In commercial operation, the expendable pattern is shaped like a cluster of several workpieces connected by a central gating tree, so that several workpieces can be cast simultaneously.

The repeated dipping, sprinkling and drying process may occur up to twelve times in order to achieve the desired thickness.

After the desired thickness is reached, the mold is flashfired or autoclaved to remove the expendable pattern and then preheated to the desired temperature(between 1600 and 2100 deg.F) in preparation for receiving the liquid metal.

The binder of the present invention employs Latrix-brand binder produced by Nalco Chemical Co.

A slurry of predominately silicate zircon is first applied to the pattern and dried. This may be repeated so that there are two ceramic layers. Thereafter, the pattern is dipped in a slurry of fused silica or silicate.

The fused silica in the slurry is a finely divided powder, preferably of a particle size so that a majority will pass through a 190-300 U.S. mesh.

The coarse grit or stucco of silicon carbide is sprinkled on the moist slurry prior to drying so as to build up a mold wall to the desired thickness. The grit may be of a particle size of 50-20 U.S. mesh.

The mold contains silicon carbide in sufficient amounts and sufficient densities to achieve rapid cooling of the metal during the solidification range. The mold contains such amounts and densities of silicon carbide so that the resulting casting will have finer grain and ductile strength more than 50% higher than minimum industry standards for castings of the same alloy. Moreover, rapid cooling in the mold is sufficiently high so that a one quarter inch cross section will freeze in less than 10 seconds.

The mold wall is built to a thickness preferably to at least the average thickness of the part to be cast so that the mold will have sufficient heat capacity.

The mold used in the process of the invention has a wall containing silicon carbide in amounts of at least 20%, preferably at least 50% and most desirably at least 60% by weight. The density of the mold wall is at least about 2.5 and preferably at least 2.7.

The alloy cast in the mold may be any alloy suitable for casting. A cobalt-based alloy was used in the examples set forth below, specifically, a cobalt-based alloy containing chromium, for example ASTM F-75. Although high carbon content in such an alloy was considered unsuitable for forging; it was found that cast preforms made from this alloy were satisfactory in closed die forging operations.

The pouring temperatures at which the metal is introduced into the mold should be as low as possible and slightly above (300 degrees F. above solidus) the point at which the metal freezes in order to facilitate rapid cooling. For example, in the cobalt-based alloys the pouring temperature may be 2700 deg.F., because the melting point is about 2400 deg. F.

The mold should be heated to 600 degrees F. below the solidus, before pouring.

After the metal is poured into the mold and has solidified, the mold is removed. The cast article is trimmed by grinding and blasted with blasting media (i.e. aluminum oxide, glass bead, etc.) to remove any oxide layer. The casting may also be heat treated prior to forging, but this is an optional process . Once the cast process is completed, the resulting preforms can be processed to produce two types of product.

The first type would take a cast preform with the same geometric outline as the finished part, but with added thickness for the forging reduction needed to improve the mechanical properties. This produces a hybrid product with much better mechanical properties than a casting, but a microstructure that is still more than 50% cast structure. This would be for applications where a casting is not quite strong enough but a forging is not needed.

The second type would utilize a cast preform in the shape of a forge bar which would be subsequently extruded and then closed die forged to produce a 100% forged quality product from cast raw material. This product would meet all the metallurgical requirements of a forging including mechanical properties and microstructure.

The following examples are presented for the purpose of further illustrating and disclosing the invention and are not to be construed as a limitation thereon.

EXAMPLE I

A hip implant was chosen for the part to be made.

A wax (Yates PC15) was used to produce the pattern. The pattern was made to the geometric outline of the hip implant, but was 3/16 in. thicker to allow for proper reduction in forging in order to improve the mechanical properties when required thickness dimensions were reached.

The wax pattern was attached to a wax cup and main metal feed runner with orientation such as to minimize turbulence when poured.

The wax assembly was washed with Nalco 6200 pattern cleaner and dipped in the primary slurry and sanded in the primary sand. The primary slurry consisted of Latrix binder, silicate zircon, cobalt zirconium (nucleation aid, 2-5 micron particle size), P1-W fused silicate, antifoam Y-30 emulsion, Nalco 8815 wetting agent and distilled water. The primary stucco was 100 mesh zircon. Fused silica designations are from Nalco Chemical Co.

After drying, the assembly was dipped in the second primary slurry and sanded with S-1 fused silicate.

After drying , the assembly was dipped in the backup slurry which contains high concentrations of fused silicate and then sanded with the special stucco sand of silicon carbide (Norton crystolon SiC 36 grit). The backup slurry consisted of Latrix binder, P-2 fused silicate, P-1 fused silicate and distilled water.

The last step of dipping in the backup slurry and sanding with silicon carbide was repeated until the desired thickness of the shell equaled the average thickness of the part to be cast. This is to assure adequate heat capacity for the hybrid shell system.

After drying, the assembly was dipped in a sealcoat of predominately fused silicate and dried. After complete drying, the assembly was placed into an autoclave and pressurized to 130 psi with steam. The wax drained out leaving just the shell forming the outer surface of the assembly. The shell was then fired at 2000 deg.F for twenty minutes to burnout any residual wax. After the shell had been fired, it was transferred to a preheat oven at about 1800 Deg. F and held at temperature for approximately twenty minutes.

At this time, alloying materials were put into a crucible and melted with argon flowing over the top of the crucible. The alloy had the following composition (percentage by weight):

Alloy Composition

C 0.23%, Mn 0.40%, Si 0.88%, Cr 27.4%, Ni 0.36%, Mo 5.52%, Fe 0.36%, Ni 0.17%, Al 0.01%, Co Balance.

When the metal has melted by induction and the temperature reached 2700 deg. F., the mold was removed from the preheat oven, placed cup down and clamped to the crucible. The mold was flushed with argon. After all was secure, the entire furnace was rotated emptying the liquid metal from the crucible into the mold. While the metal entered the mold, argon was pressurized to insure quick filling.

The mold was removed from the furnace and exothermic materials (Foseco, FRX-CP-5292A) were added to the cup to promote extended feeding of metal during solidification.

After cooling, the parts were trimmed by cutting pieces from gates with an abrasive cutoff saw, ground on a belt grinder and cleaned with a grit blast medium.

The cast preform blanks were heated to temperatures between 2050-2250 Deg.F. The heating time is dependent on the mass of casting blanks and can vary from 15 minutes to 30 minutes.

The forging die was the same as used for wrought material. Three impressions, blocker, semi-finisher and finish were used to forge down the preformed blanks.

After heating for a sufficient time to obtain uniform temperature throughout the casting; the following operations were performed in a closed forging die:

One light blow in the blocker impression for locating,
Two medium blows and a full blow in the blocker impression,

One full blow in the semifinish impression,

One full blow in the finish impression,

Hot trim to remove excess metal in a mechanical press.

Thereafter, the part was air cooled and then grit blasted to remove surface oxides and provide a uniform surface finish.

Table I

The properties and microstructure obtained in using the process set forth in Example I are as follows:

Mechanical Properties of Cast Preform (2 samples)

Tensile (ksi)	Yield (ksi)	Elongation	% R/A %
114	66.4	26.5%	31.5%
115	66.5	23%	34.5%

Mechanical Properties of Forged Hybrid (2 samples)

Tensile (ksi)	Yield (ksi)	Elongation %	R/A%
184	134	21	13.9
187	135	15	13.8

Metallographic Examination of Forged Hybrid

Grain size (ASTM E 112) 40% of cross section is equiax grain 7-9

60% of cross section is columnar cast structure, grain 3-00

The physical properties obtained from the forged hybrid of Example I are comparable to wrought properties for alloy of the same chemical composition. However, the microstructure would be unacceptable to wrought standards for this alloy.

EXAMPLE II

The finished product for this example was the same hip implant used in Example I.

The casting portion of this process was the same as Example I with the exception of the wax pattern being made to match the bar diameter and length needed for extruding rather than to the geometric shape of the finished part as in Example I. If the cast bars are formed as a cluster including several bars or as a multi-workpiece bar, the workpieces are separated into individual workpieces or preformed blanks of bars before extrusion. Preferably, each workpiece is extruded as a separate piece.

The preformed cast bars were then heated to between 2000-2250 deg. F. for 15-30 minutes. An optional ceramic coating can be applied to the bars in varying thickness to produce the desired lubrication, but this is not necessary for the process.

When the bars had been uniformly heated, they were put into an extrusion tool in a hydraulic press where a portion of the 1 inch diameter bar was forced through a 5/8 inch diameter hole. This changed the 6 inch long, 1 inch diameter preform into a 9 inch long extrusion(2 1/2 in. at 1.12 dia. and 6 1/2 in. at 5/8 diameter.) This required between 50-100 tons of pressure.

This preliminary forging process (extrusion) was designed to reduce the material sufficiently as to produce high levels of forged grain which would increase the forgability by providing an even stronger preform and produce a finished product with entirely forged microstructure.

Referring to Figures 3-8, the cast workpiece 20 begins as a bar with a reduced-diameter nose 21, as shown in Figure 3. Figure 3, shows the extrusion punch 22, the workpiece 20, the collar 23, the extrusion die insert 24, the extrusion knock-out guide 25, and the extrusion knock-out punch 26. In Figure 4, the workpiece is inserted into a bore 27 in the collar 23 and the extrusion die insert 24. In Figure 5, the extrusion punch 22 is pressed into the bore 27 so that the workpiece 20 is extruded along the bore to a reduced diameter. In Figure 6, the collar 23 and the extrusion die insert 24 are separated. In Figure 7, the extruded workpiece 20 is pressed out of the bore 27 by the extrusion knock-

out punch 26. In Figure 8, the nose 21 and endpiece 28, which were not subject to the full extrusion action, may be removed from the workpiece 20. However, in the forming of some products, and in particular, hip replacements, the nose 21 and endpiece 28, can be incorporated into the forged product design even though they were not subject to the full extrusion action. This is because the work that will be added in the forging step will do some refining of the microstructure, and because the geometry and specific performance demands ends of the hip replacement allow this approach.

After extruding, the parts were shot blasted to clean and smooth the surface for forging.

The same forging tool was used as in Example I with the addition of a pre-forging bending operation for the extrusion. The blows were as follows:

A) 1 light blow in the bender,
B) 3 light blows, 4 medium blows, 1 full blow in the blocker impression,
C) 1 light blow, 1 medium blow, 1 full blow in the semi-finish impression,
D) 1 light blow, 1 medium blow, 1 full blow in the finish impression, and
E) Hot trim excess metal in mechanical press

After forging, the parts can be air cooled or water quenched with no appreciable difference in properties or carbide distribution.

The part is then grit blasted to remove oxides and provide uniform surface finish.

The mechanical properties and microstructure of the product produced in Example II are as follows:

Table II

Tensile (ksi)	Yield (ksi)	Elongation%	R/A%
196	147	12.8	16.1
195	145	13.2	16.6

Metallographic Examination:

Grain size(ASTM E 112) 100% forged equiaxed, grain size 10 with some as large as 9. No residual cast structure visible.

Unlike the process in Example I which produces a high strength cast product; the process in Example II produces a 100% forged quality product, but it does so using cast bar rather than wrought bar. This will be a forging produced with more flexibility in chemical composition, for much less cost than forgings produced from wrought bar. Both forging examples are dependent on the uniqueness of the casting process and both forged hybrids have potential applications in the marketplace.

The theoretical basis for the invention is in part not entirely known. It has been observed that castings with higher elongations also had finer dendritic grain structure. It also has been observed that the distance between the dendrite limbs was related to the cooling rate through the solidification range as the metal freezes. It is believed that the dendritic structure achieved by rapid cooling as outlined above, can result in elongations approaching or equal to wrought bars, so that castings produced according to the invention can for that reason be forged.

It is well established that cast grain can be refined to stronger forged grain by a combination of speed of flow and volume reduction (more speed and reduction producing finer grain). We have capitalized on this with our extrusion process in combination with the forging of the extrusion to produce the same grain refinement in our cast preform as is produced in the rolling process of wrought bar. This gives us a finished product that is a wrought product in every respect.

This invention also involves a novel material and melting-and-mixing process for use with the present invention and otherwise. The novel material is a metal-matrix composite material which can be melted and cast to form a starting material for the present cast-forge process or the present cast-extrude-forge process for manufacturing high strength metal parts such as synthetic hip joint replacement parts. The melting-and-mixing process uses induction heating coils, set at an optimum power and frequency level, to not only melt the metal-matrix composite material, but also the keep the molten material

turbulently mixed to maintain a uniform distribution of particles on the metal matrix before pouring.

The metal-matrix composite is a mixture of ceramic particles and a metal matrix (preferably in the form of stainless steel). The mixture is heated to melt the metal matrix and then mixed to maintain a uniformed distribution of the particles within the metal matrix. The material is then poured into special highly, thermally-conductive molds described above. The metal freezes while the ceramic is still well distributed within the matrix so that the solid metal-matrix product has a uniform distribution of particles throughout. Referring to Figure 9, the starting materials of ceramic powder 31 and metal 32 are melted together using induction heating coil 33 and power source 34, in a melting pot 35. The power and frequency of the induction heating are selected to optimize the turbulence of the melt in order to maintain a highly uniformed distribution of the solid particles within the molten metal. In the preferred process, the metal is melted and the frequency and power adjusted so the molten metal achieves a rolling turbulence. For 316 stainless steel and particular equipment, the metal is held at 3100 deg. F. at a frequency of 8 kilohertz. The particles are added and they are drawn into the molten metal and maintained in uniform distribution. The melting is done in an inert environment 36 if that is necessary to prevent undesired reactions. The metal is maintained at a very slight superheat and poured into a highly conductive shell mold 37 with the metal at a temperature slightly above freezing. The pouring of the mixture into the highly conductive mold causes very rapid solidification of the metal-matrix body, so that there is very little segregation of the solid particles and the metal and a uniform distribution of the particles within the metal is achieved. Furthermore, the rapid cooling of the molten body causes very fine grain structure in the metal so that a strong and highly ductile composite is achieved.

The cast workpiece is then optionally exposed to an extrusion process which creates substantial reduction in the cross-section of the workpiece and, as a result, further refines the grain structure. Finally, the extruded piece (or the cast piece if extrusion is not employed) is exposed to a series of forging processes which bring the workpiece to a final shape with a significant amount of bulk flow to further refine the grain structure and achieve forged workpiece microstructure in the matrix and high strength and ductility.

The particles 31 are typically aluminum oxide or zircon particles in the two to five micron particle size range. The ceramic particles are present in the mix in a 5 to 25%, and preferably 10% to 15%, by volume concentration. The specific gravity of the particles is typically about 2.5.

The metal 32 is preferably a stainless steel, for example, 316. Typical cast 316 alloy has a minimum tensile strength of about 30 ksi. However, using the present process minimum levels of 90 ksi can be achieved with 30% to 31% elongation. Another preferable alloy involves a high nitrogen stainless steel, such as alloy 22-13-5. The metal would typically have a specific gravity of approximately 8. The metal should have a melting point of at least 1000 deg. C., preferably at least 1500 deg. C., and ideally 2000 deg. C. The composite and mixing process are primarily of value for the high performance alloys such as the stainless steels, nickel-based super alloys, iron-based super alloys, titanium and titanium alloys. The composite and mixing process are primarily of value for the high density alloys, that is alloys having a specific of at least 4, preferably at least 7, and optimally at least 8.

While it will be apparent that the illustrated embodiments of the invention herein disclosed are calculated adequately to fulfill the object and advantages primarily stated, it is to be understood that the invention is susceptible to variation, modification, and change within the spirit and scope of the subjoined claims.

The invention having been thus described, what is claimed as new and desire to secure by Letters Patent is:

Claims:

1. A process for manufacturing a metal article by casting a preformed blank and thereafter forging said cast preformed blank, the steps comprising:

a) forming a mold, said mold comprising silicon carbide particles and said mold being of sufficient density for substantial conductive heat extraction through said mold so as to achieve rapid cooling of molten metal placed in the mold,

b) introducing molten metal alloy into said mold,

c) rapidly cooling said molten metal alloy during the solidification phase to form a preformed blank,

d) forging said preformed blank using extrusion, or closed die forging or both to form a final forged workpiece of a desired configuration and microstructure.

2. A method as recited in claim 1, wherein the mass for the metal introduced into the mold is only slightly greater than the mass of the final forged workpiece.

3. A method as recited in claim 1, wherein the mass for the metal introduced into the mold is less than 10% greater than the mass of the final forged workpiece.

4. A method as recited in claim 1, wherein said rapid cooling conducted at a rate sufficiently high during solidification phase so that the resultant solid cast preformed blank has a grain structure which is substantially more equiaxed and has substantially smaller average grain size than industry standard for cast alloys of the same chemical composition,

5. A method as recited in claim 1, wherein said rapid cooling conducted at a rate sufficiently high during solidification phase so that the resultant solid cast preformed blank has an increased in ductile strength of about 50% over industry standard minimums for

alloys of the same chemical composition,

6. A method as recited in claim 1, wherein said alloy is a cobalt based metal alloy.

7. A method as recited in claim 1, wherein the carbon content of said cobalt based alloy is above 0.2% by weight.

8. A method as recited in claim 1, wherein said alloy is a metal-matrix composite comprising a uniform distribution of ceramic particles within a metal matrix formed of a metal having a melting point above 1000 deg. C.

9. A method as recited in claim 1, wherein the forging of said the preformed blank comprises the step of:

a) closed die forging of the preform blank to form a final forged workpiece of a desired configuration and microstructure.

10. A method as recited in claim 1, wherein the forging of said the preformed blank comprises the steps of:

a) extruding the preformed blank to form a bar of cross-section smaller than the blank, and

b) closed die forging of the bar to form a final forged workpiece of a desired configuration and microstructure.

11. A method as recited in claim 1, wherein the final forged workpiece is a hip replacement.

12. An article produced according to the process of claim 1.

13. An article produced according to the process of claim 9.

14. An article produced according to the process of claim 10.

15. A hip replacement produced according to the process of claim 1.

16. A hip replacement produced according to the process of claim 9.

17. A hip replacement produced according to the process of claim 10.

18. In a method for making a cast and forged metal article, comprising the steps of:

a) preparing an expendable pattern of the part to be cast,

b) dipping said pattern into slurry of fused silica and a binder to form a moist coating,

c) sprinkling silicon carbide grit on said moist coating,

d) drying said moist coating,

e) repeating steps b), c), and d) until said shell is built up to the desired thickness, and

f) casting a metal article in said mold to form a preform blank, and

g) subjecting said preform blank to extrusion, closed die forging or both to produce desired mechanical properties and microstructure.

19. A method as recited in claim 18, wherein the mass for the metal introduced into the mold is only slightly greater than the mass of the final forged workpiece.

20. A method as recited in claim 18, wherein the mass for the metal introduced into the mold is less than 10% greater than the mass of the final forged workpiece.

21. A method as recited in claim 18, wherein said rapid cooling conducted at a rate sufficiently high during solidification phase so that the resultant solid cast preformed blank has a grain structure which is substantially more equiaxed and has substantially smaller average grain size than industry standard for cast alloys of the same chemical composition,

22. A method as recited in claim 18, wherein said rapid cooling conducted at a rate sufficiently high during solidification phase so that the resultant solid cast preformed blank has an increased in ductile strength of about 50% over industry standard minimums for alloys of the same chemical composition,

23. A method as recited in claim 18, wherein said alloy is a cobalt based metal alloy.

24. A method as recited in claim 18, wherein the carbon content of said cobalt based alloy is above 0.2% by weight

25. A method as recited in claim 18, wherein said alloy is a metal-matrix composite comprising a uniform distribution of ceramic particles within a metal matrix formed of a metal having a melting point above 1000 deg. C.

26. A method as recited in claim 18, wherein the forging of said the preformed blank comprises the step of:

a) closed die forging of the preform blank to form a final forged workpiece of a desired configuration and microstructure.

27. A method as recited in claim 18, wherein the forging of said the preformed blank comprises the steps of:

a) extruding the preformed blank to form a bar of cross-section smaller than the blank, and

b) closed die forging of the bar to form a final forged workpiece of a desired configuration and microstructure.

28. A method as recited in claim 18, wherein the final forged workpiece is a hip replacement.

29. An article produced according to the process of claim 18.

30. An article produced according to the process of claim 26.

31. An article produced according to the process of claim 27.

32. A hip replacement produced according to the process of claim 18.

33. A hip replacement produced according to the process of claim 26.

34. A hip replacement produced according to the process of claim 27.

35. A metal-matrix composite comprising a uniform distribution of ceramic particles within a metal matrix formed of a metal having a melting point of at least 1000 deg. C. and a specific gravity of at least 4.

36. A composite as recited in claim 35, wherein the particles are aluminum oxide.

37. A composite as recited in claim 35, wherein the particles are zircon.

38. A composite as recited in claim 35, wherein the particles are in the two to five micron particle size range.

39. A composite as recited in claim 35, wherein the particles are present in the mix in a 5% to 20% by volume concentration.

40. A composite as recited in claim 35, wherein the particles are present in the mix in a 10% to 15% by volume concentration.

41. A composite as recited in claim 35, wherein the particles are present in the mix in a 12% by volume concentration.

42. A composite as recited in claim 35, wherein the specific gravity of the particles is 2.0 to 3.0.

43. A composite as recited in claim 35, wherein the specific gravity of the particles is about 2.5.

44. A composite as recited in claim 35, wherein the metal is a stainless steel.

45. A composite as recited in claim 35, wherein the metal is IN 316

46. A composite as recited in claim 35, wherein the metal has a tensile strength of about 30 ksi.

47. A composite as recited in claim 35, wherein the metal is a high nitrogen stainless steel.

48. A composite as recited in claim 35, wherein the metal is alloy 22135.

49. A composite as recited in claim 35, wherein the metal has a specific gravity of 6 to 10.

50. A composite as recited in claim 35, wherein the metal has a specific gravity of approximately 8.

51. A composite as recited in claim 35, wherein the composite has a minimum tensile strength of greater than 80 ksi with 28% to 33% elongation.

52. A composite as recited in claim 35, wherein the composite has a minimum tensile strength of 90 ksi with 30% to 31% elongation.

53. A method for shaping a metal object comprising the steps of:

a) forming a molten mass having a distribution of ceramic particles within a metal matrix,

b) maintaining turbulence within the molten mass by exposing the mass to an alternating current electromagnetic field of such power and frequency that a level of turbulence is induced in the mass so that the ceramic particles are maintained uniformly distributed within the metal matrix,

c) While the mass is molten and the ceramic particles are uniformly distributed within the metal matrix, pouring the mass into a mold, and

d) allowing the mass to solidify in the mold, while the ceramic particles are uniformly distributed within the metal matrix.

54. A method as recited in claim 53, wherein the particles are aluminum oxide.

55. A method as recited in claim 53, wherein the particles are zircon.

56. A method as recited in claim 53, wherein the particles are in the two to five micron particle size range.

57. A method as recited in claim 53, wherein the particles are present in the mix in a 5% to 20% by volume concentration.

58. A method as recited in claim 53, wherein the particles are present in the mix in a 10% to 15% by volume concentration.

59. A method as recited in claim 53, wherein the particles are present in the mix in a 12% by volume concentration.

60. A method as recited in claim 53, wherein the specific gravity of the particles is 2.0 to 3.0.

61. A method as recited in claim 53, wherein the specific gravity of the particles is about 2.5.

62. A method as recited in claim 53, wherein the metal is a stainless steel.

63. A method as recited in claim 53, wherein the metal is IN 316

64. A method as recited in claim 53, wherein the metal has a tensile strength of about 30 ksi.

65. A method as recited in claim 53, wherein the metal is a high nitrogen stainless steel.

66. A method as recited in claim 53, wherein the metal is alloy 22135.

67. A method as recited in claim 53, wherein the metal has a specific gravity of 6 to 10.

68. A method as recited in claim 53, wherein the metal has a specific gravity of approximately 8.

69. A method as recited in claim 53, wherein the mold has walls which include silicon carbide particles.

70. A method as recited in claim 53, wherein the mold has walls which include silicon carbide particles having a particle size of 50-20 U.S. mesh.

71. A method as recited in claim 53, wherein the mold has walls which include silicon carbide particles in amounts of at least 20% by weight.

72. A method as recited in claim 53, wherein the mold has walls which include silicon carbide particles in amounts of at least 50% by weight.

73. A method as recited in claim 53, wherein the mold has walls which include silicon carbide particles in amounts of at least 60% by weight.

74. A method as recited in claim 53, wherein the mold has walls of thickness being at least the average thickness of the article to be cast.

75. A method as recited in claim 53, wherein the mold has walls which include silicon carbide particles and the amounts and densities of silicon carbide are such that the resulting casting will have finer grain and ductile strength more than 50% higher than minimum industry standards for castings of the same alloy.

76. A method as recited in claim 53, wherein the mold has walls which include silicon carbide particles and the amounts and densities of silicon carbide are such that a one quarter inch cross section of molten metal poured into the mold will freeze in less than 10 seconds.

77. A method as recited in claim 53, wherein the mold has walls having a density of at least 2.5.

78. A method as recited in claim 53, wherein the mold has walls having a density of at least 2.7.

FIG. 1

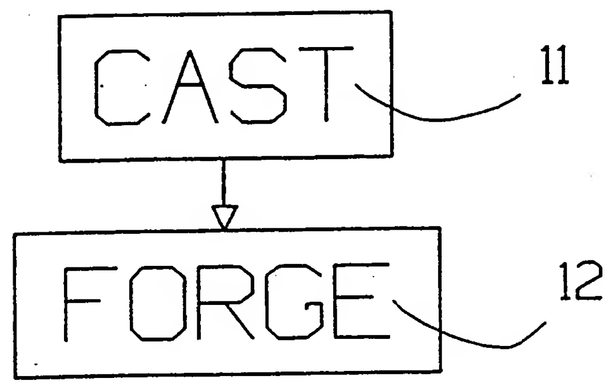
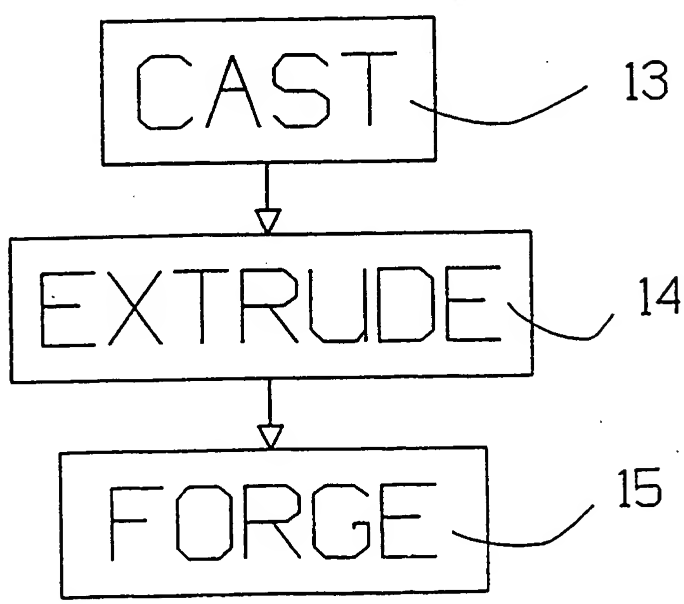


FIG. 2



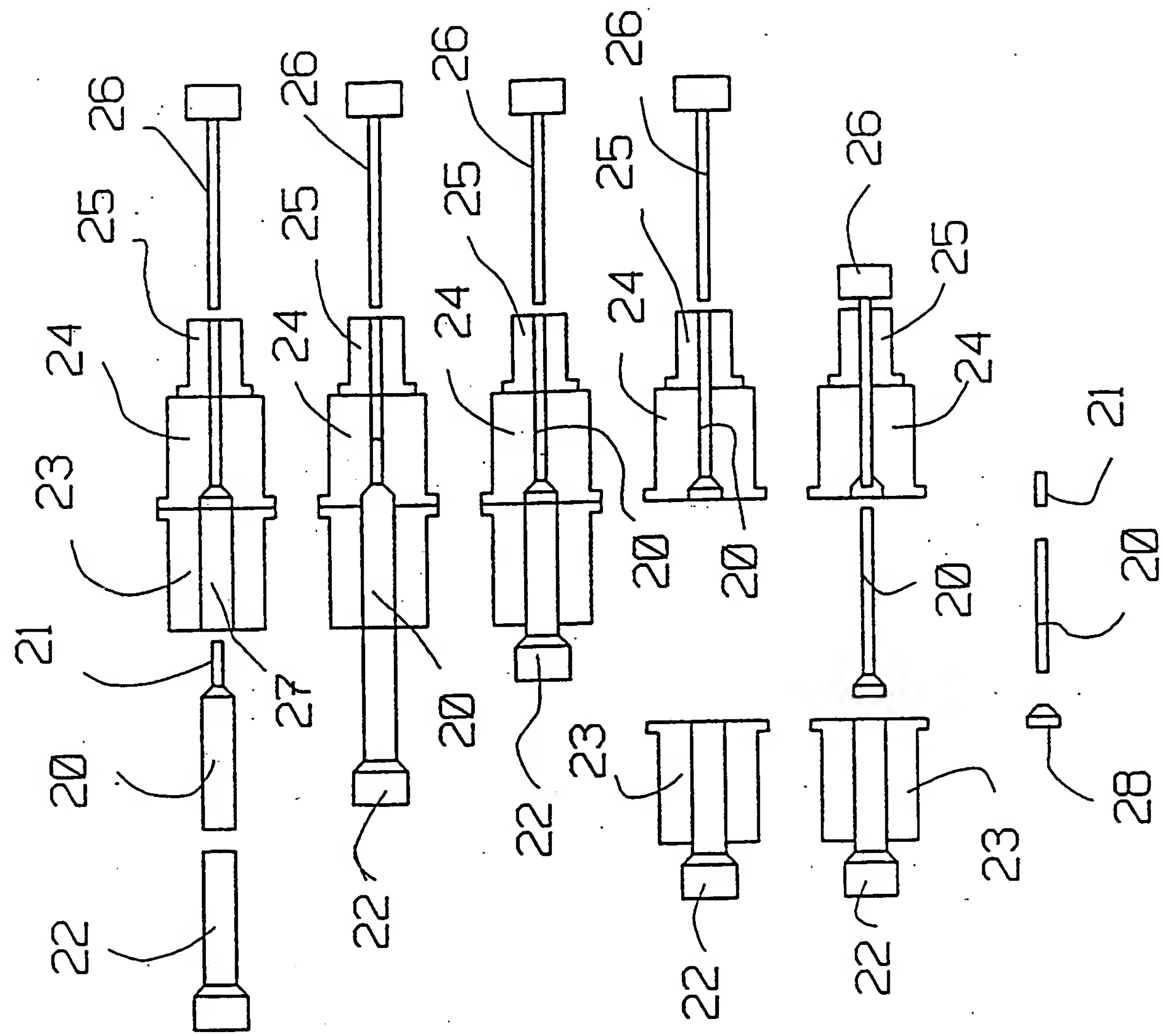


FIG. 3

FIG. 4

FIG. 5

FIG. 6

FIG. 7

FIG. 8

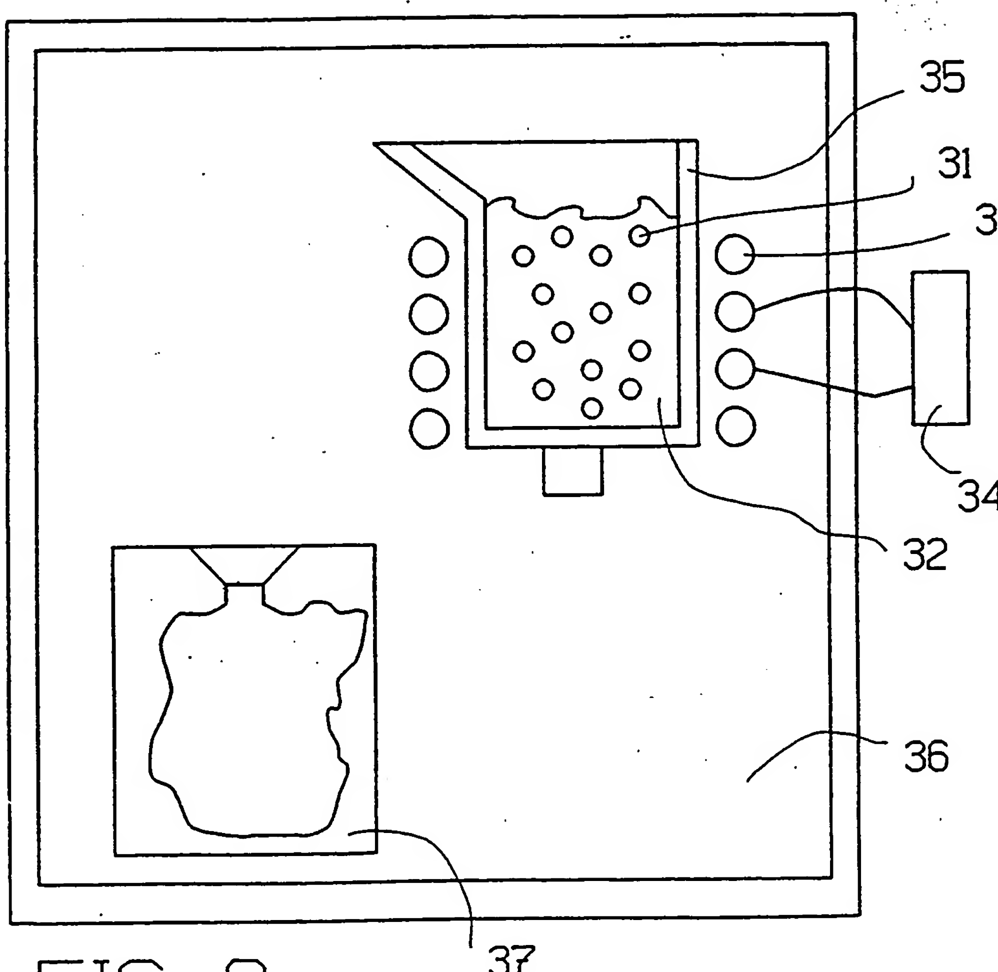


FIG. 9